PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Art Unit: 1742
Examiner: Roe, Jessee Randall

In re application of

M. Dilmore et al.

Serial No. 10/761,472

Filed: January 21, 2004

Title:
Eglin Steel – A Low Alloy High Strength Composition

Attorney Docket 040650

DECLARATION OF JOHN PAULES
UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, John R. Paules, depose and say as follows:

1. I am employed as General Manager of Ellwood Materials Technologies, a subsidiary of Ellwood Group, Inc., the parent of Ellwood National Forge, Co., the present owner of the patent application referenced above (the "present application").

2. I earned B.S. and M.Eng.degrees in Metallurgy and Materials Science from Lehigh University in 1976 and 1981, respectively, and have worked in the field of steel metallurgy for 30 years. I am a registered Professional Engineer in the Commonwealth of Pennsylvania. I have worked with Ellwood Materials Technologies since 1997 with various steel alloy development programs, including the development and testing of Eglin Steel, the low alloy steel described in the present application. In particular, I am responsible for development of melting, forging, and heat treatment practices which result in mechanical properties and service performance which meet requirements. I have directed research studies of the fine scale microstructure of Eglin Steel to gain a full understanding of the effect of fine precipitate particles on properties such as strength and toughness. I have published and presented a technical paper on the development and properties of Eglin Steel.

3. Eglin Steel utilizes a low tempering temperature (400-500°F) in combination with high Si and W contents to produce a balance of ultra high strength of between 233-270 ksi and good toughness. The unique combination of properties obtained with the combination of elements and processing is critical for specialized ordnance applications, such as penetrator bombs. Exhibit 1 attached hereto presents portions of an ordering document submitted to Ellwood National Forge Co. for materials for warheads. The ordering document sets forth the requirements for the alloy steel, including a *minimum* ultimate tensile strength of 245 ksi (173 kg/mm^2). Table 3 of the subject application for Eglin Steel shows that a minimum ultimate tensile strength of 245 ksi was easily attained in tests run on several preferred compositions. The heat treatment used with Eglin Steel produces what I have found to be a unique combination of mechanical properties. Eglin Steel is tempered at a low temperature, of about 400-500°F, to produce a very high tensile strength level, typically about 1,725 MPa (ultimate tensile strength ranging from about 233 to 271 ksi and typically, about 245 ksi, as shown in Table 3 of the present application) and a Charpy V-notch impact strength, typically of at least about 20 ft.lbs. at -40°F (ranging from about 17 to 43 ft.lbs. at -40°F , as shown in Table 3 of the present application). The low tempering temperature also imparts a high degree of strain hardening (a low yield strength/tensile strength ratio). This strain hardening is an important feature which helps components such as penetrator bombs absorb high strain without fracturing.

4. On information and belief, the U.S. Patent Office issued an Office Action dated April 9, 2007, rejecting the claims of the present application based primarily on the information disclosed in the following patent publications (the "Referenced Patents"):
U.S Patent No. 3,574,602 to Gondo et al.;
U.S. Patent No. 5,454,883 to Yoshie et al.

5. I have reviewed the present application, the April 9, 2007 Office Action and the Referenced Patents. Based on my experience in metallurgy and with high strength alloy steels in particular, it is my opinion that the materials described in the Referenced Patents would not produce an alloy steel having the critical properties of Eglin Steel for the reasons stated below.

6. In the Office Action, the Examiner stated, with respect to the Yoshie patent, that Yoshie et al. "teach tensile strengths up to 160 kg/mm^2 (227 ksi), which are tensile strengths that closely resemble the tensile strengths of ES-1 and ES-3 in Table 3 of the instant specification." The Examiner concluded that Yoshie et al. would inherently have a Charpy V-notch impact

strength of about 20-43 at -40°F, an ultimate tensile strength in the range of about 233-270 ksi, and a strain-to-failure rate of about 15.1 to about 16.6% because Yoshie et al. teach comparable tensile strength and substantially the same composition as that of the claimed invention."

7. In my opinion, the material of Yoshie et al. would not have the impact strength, ultimate tensile strength and strain-to-failure rate of Eglin Steel. Yoshie et al. teach heating, or tempering the steel to a temperature of Ac_1 or higher. (*See*, for example, col. 16, lines 42-64, col. 22, Table 3 and col. 26, Table 7.). A temperature of Ac_1 means the lower transformation temperature of steel, wherein, upon heating, a partial transformation of the quenched Martensite phase to the higher temperature Austenite phase occurs. The Ac_1 temperature is higher than normal tempering temperatures, which range from about 1000 °F to 1200 °F. That temperature is significantly higher than the tempering temperature used to produce Eglin Steel (i.e. 400-500 °F.)

8. On information and belief, there are three typographical errors in Table 12 of the Yoshi patent that erroneously display higher than actual ultimate tensile strength results. In this table, the correct tensile strength (TS) results for examples No. 12, 13, and 17 are 80, 82, and 82 kgf/mm² respectively, not 180, 182 and 182 kgf/mm². These errors are clear when considering the yield strength/tensile strength ratio shown in sixth column of the table (*e.g.* in example 12, the YS = 56 and the YR = YS/TS = 70%, so the TS = 56 / 0.70 = 80, not 180. Similar calculations confirm the same error for examples 13 and 17 and that all other values in Table 12 are correctly calculated (*e.g.*, in example in Example 1, the values given are YS = 52, YR = 74% and TS = 70; YR = YS/TS = 52/70 = 0.74, or 74%, the given value for YR.).

9. In the Office Action, the Examiner stated that "Gondo et al. teach tensile strengths that range from 130-159 kg/mm^2 (184-226 ksi), which are tensile strengths that closely resemble the tensile strengths of ES-1 and ES-3 shown in Table 3 of the instant specification. The alloy steel of Gondo et al. ('602) would inherently have a Charpy V-notch impact strength of about 20-43 at –40 °F, an ultimate tensile strength in the range of about 233-270 ksi, and a strain-to-failure rate of about 15.1 to about 16.6% because Gondo et al. ('602) teach (col. 1, lines 14-24) comparable tensile strength and substantially the same composition as that of the claimed invention." The Gondo patent describes alloys having tensile strengths from 130-159 kg/mm^2 (*see* the Table at col. 4), which is equivalent to about 185 – 226 ksi, and <u>not</u> 233-270 ksi.

10. The Examiner stated in response to my Declaration of January 16, 2007, that no factual evidence was provided that the steel of Gondo et al. would not have the ultimate tensile strength, Charpy V-notch impact strength and ductility high rate strain to failure values described in the subject application. Gondo et al. do not specifically teach how to make the alloy steel. No direct tempering temperatures or other processing steps are taught. One skilled in the art is left to guess at how Gondo et al. made the described alloy. The only reference that one skilled in the art might look to for guidance as to how to make the Gondo et al. alloy steel is the reference in col. 2, lines 5-12, wherein Gondo indicates that they improved upon conventional high tension steels by adding to such steels Ti, Zr and B and at least one of Sn, Sb and As. Other than the optional addition of other elements, no other modification of the conventional steels is suggested and no modification to conventional processes is taught or suggested. In the absence of any specific teaching to the contrary, one must conclude that Gondo used conventional processing steps to produce the alloy steel. Conventional processing steps at the time the Gondo application was filed, (1967) would include tempering temperatures of 1000 °F and higher. Use of tempering temperatures in that range would preclude the alloy described in Gondo et al. from having ultimate tensile strength properties like those described in the subject application.

11. Attached as Exhibit 2 are two graphs showing how hardness decreases with increasing tempering temperature in steels of various carbon contents (Figure 17.2, from M. A. Grossman and E. C. Bain, *Principles of Heat Treatment,* 5th ed., ASM, 1964) and how yield strength and ultimate tensile strength decrease (and tensile elongation and reduction of area increase) with increasing tempering temperature (Figure 17.4, from *Modern Steels and Their Properties*, Handbook 2757, 7th ed., Bethlehem Steel Corp., Bethlehem, PA, 1972). Brinell Hardness (HB) is shown on the x-axis along with the tempering temperature in the second graph. The high tempering temperatures employed by Yoshie (Ac_1 lower transformation temperature and higher) and Gondo et al. (conventional tempering temperatures) preclude the attainment of the ultra high strength levels achieved with Eglin Steel.

12. The claimed alloy of the present application has much higher ultimate tensile strengths, and as stated above, the ultimate tensile strength achieved by Eglin Steel is critical for certain applications. Steels having tensile strengths like those reported for Gondo et al. and Yoshie et al. are too low to be useful for target penetration. The Charpy impact strength properties would not be expected to be comparable to those found for Eglin Steel. Therefore, the materials described in the Gondo et al. and Yoshie et al. patents would be incapable of

performing the tasks for which Eglin Steel was invented. Notwithstanding overlap in the ranges of some elements, the unique combination of elements in the amounts disclosed and claimed in the present application together with the heat treatment used with Eglin Steel produces a unique and unexpected combination of mechanical properties which are critically different than those in the Referenced Patents.

13. I further declare that all statements made herein are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or document or any registration resulting therefrom.

John R. Paules

7/5/2007

Date

Exhibit 1

[redacted]

Contract: [redacted]

Statement of Work

29 Jun 04

1. Background

The Air Force Research Laboratory, Munitions Directorate (AFRL/MN) has developed a new 2000-lb, MK-84 type warhead [redacted]. The [redacted] improvements [redacted] include a case fabricated from high-strength steel, the addition of a [redacted]. A total of 16 prototype cases have been fabricated and tested for weapon survivability. The bomb cases were fabricated from ES-1c steel (a high-strength steel jointly developed by AFRL/MN and Ellwood National Forge Co. (ENF)). In support of this effort, 20 full-scale warhead case assemblies are needed to continue developmental testing [redacted]. It is anticipated that approximately 20 to 25 additional cases may also be required to satisfy operational testing requirements.

2. Objective

The primary objective under this contract is for the Contractor to produce ES-1c steel with the required strength properties, and from that, to fabricate test warheads in accordance with the Technical Data Package (TDP) and deliver them to the Air Force. All delivered warheads shall be fabricated and assembled in accordance with the TDP, which will be provided separately.

3. Work to be accomplished

a. ES-1c STEEL (CLIN 1)

(1) The Contractor shall produce ES-1c steel in the form of forged ingots. Prior to the Contractor fabricating any warhead cases or subcomponents using ES-1c steel, AFRL will qualify the steel material for each forged ingot by conducting a suite of mechanical property tests on heat-treated specimens obtained from the forged ingots.

(2) The Contractor shall prepare the test specimens as follows: heat-treat a minimum of one qualification sample ring from each forged ingot. These rings will be heat-treated in the same furnace that will be used to heat-treat the warhead. These test rings will have a minimum diameter of 8.0"; a wall thickness of 1.25"; and a minimum length of 7". Two pieces of steel, each approximating the mass of [redacted] warhead, will be heat-treated along with the qualification test rings to simulate a typical heat-treat load. The Contractor will provide to AFRL three tensile and six Charpy impact specimens from each test ring.

(3) The required properties to be obtained from the specimen tests are listed below. The "Single Test Minimum" refers to the minimum properties for any single test specimen. The

[redacted]
Attachment #2

"Average" refers to the minimum average of at least three test specimens from any single qualification control ring.

Qualification Test Properties	Single Test Minimum	Average (of at least 3)
Ultimate Tensile Strength	Yu = 245 ksi	Yu = 248 ksi
Static Yield Strength	Ys = 184 ksi	Ys = 188 ksi
% Strain to Failure	Sf = 11.5%	Sf = 12.0%
Charpy Impact (at -40°F)	CI = 16 ft-lbs	CI = 17 ft-lbs

(4) AFRL will conduct tests on the provided specimens to verify the steel meets the above minimum strength properties. Tensile properties will be determined using the Engineering Stress-Strain Data from AFRL's class B-1 (ASTM) extensometer-based system. AFRL will notify the contractor which forged ingots meet minimum properties and are suitable for further use in the fabrication phase (CLIN 2). If any forged ingot is determined to be inadequate, the Air Force retains the right to forego its use in the manufacture of any warheads.

b. FABRICATION (Machining And Assembly) (CLIN 2)

(1) Using the AFRL approved/accepted forged ingots, the Contractor shall machine, fabricate, heat treat, and assemble each warhead in accordance with the TDP. Every time a warhead case is heat-treated, a quality control ring obtained from the forged ingot that was used to fabricate the warhead will be heat-treated along with the warhead. The Contractor will again provide to AFRL three tensile and 6 Charpy impact specimens machined from each quality control ring. The minimum and average properties called out in paragraph 3.a. above apply to the quality control rings and the associated machined cases. Any machined cases that are associated with quality control rings that do not meet the above listed criteria, in the case of Tensile properties using the Engineering Stress-Strain Data from AFRL's class B-1 extensometer-based system, will not be accepted as deliverables under this contract.

Note: The warhead lug insert load test ("push-pull") specified in the TDP is not required for this contract. Selected warheads may be tested at another facility at a later date.

(2) The contractor shall measure the mass and center of gravity of each warhead in both unassembled [redacted] and fully-assembled [redacted] state and deliver the resulting data in accordance with CDRL [redacted]

[redacted]
Attachment #2

Exhibit 2

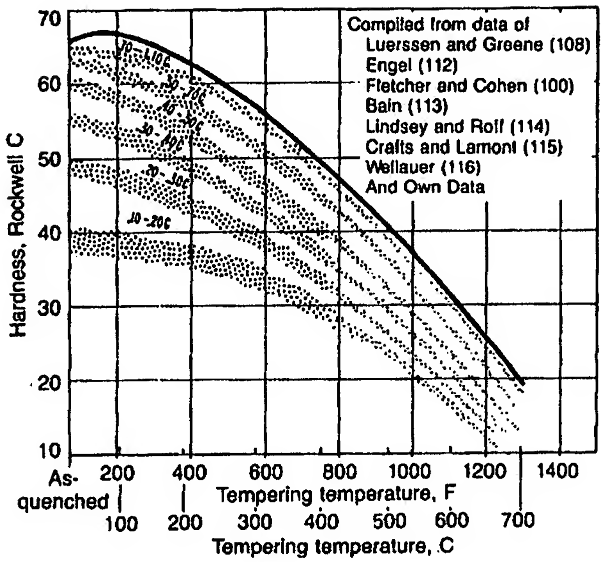

Fig. 17.2 Decrease in hardness with increasing tempering temperature for steels of various carbon contents. Ref numbers after investigators are from list in Grossmann and Bain. Source: Ref 17.1

Oil-quenched 4340

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.41	.67	.023	.018	.26	1.77	.78	.26	6-8

Critical Points, F: Ac_1 1350 Ac_3 1415 Ar_3 890 Ar_1 720

Treatment: Normalized at 1600 F; reheated to 1475 F; quenched in agitated oil.
.530-in. Round Treated; .505-in. Round Tested. As-quenched HB 601.

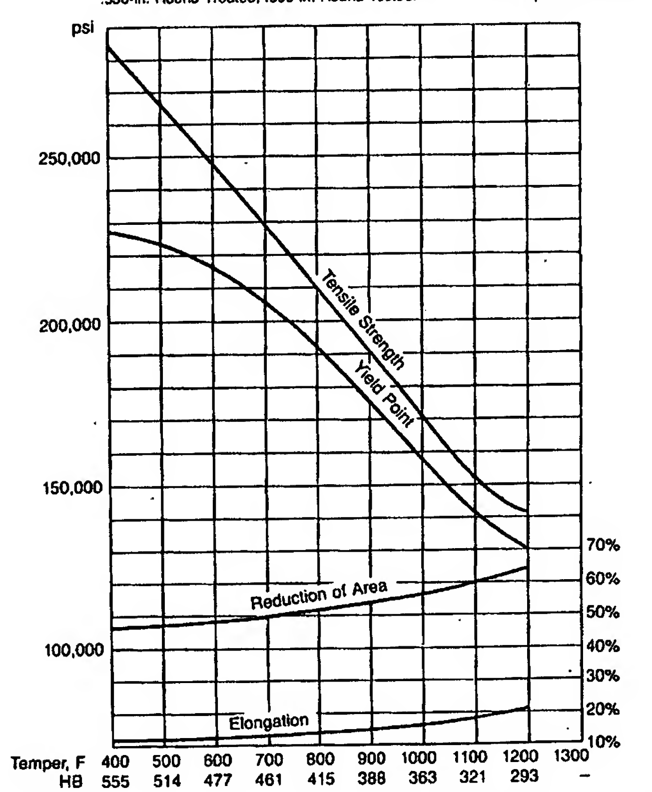

Fig. 17.4 Change in mechanical properties with tempering temperature for oil-quenched 4340 steel. Source: Ref 17.3